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Comparative Anatomy of Salt Cedar (Tamarix Pentandta Pall.) Growing in Two Habitats

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COMPARATIVE ANATOMY OF SALT CEDAR (*Tamarix pentandra* Pall.) GROWING IN TWO HABITATS

being

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THESIS ABSTRACT

Salt cedar (Tamarix pentandra Pall.) is a phreatophyte which has created a major water conservation problem in the southwestern part of the United States. This plant has the ability to adapt to many different types of habitats. It may be found growing in xeric chalk flats, in heavy clay loam soils, and in mesic sandbars near streams. It was the purpose of this study to determine any variation in the internal anatomy of the plant due to a difference in the habitat in which it was growing.

Two distinct habitats, a mesic sandbar and an upland shelterbelt, were selected to measure the differences in the internal anatomy. Samples of the roots, stems, and leaves from each habitat were collected and placed in F. A. A. solution. The samples were then sectioned, stained, and mounted on slides. The diameter of the vessel tubes, the length of the vessel tubes, the number of vessel tubes per unit area, and the thickness of the cork tissue were the criteria used to measure the difference between the roots and stems of plants growing in the two habitats. Criteria used to measure the difference in the anatomy of the leaf were the thickness of the cuticle, the number of stomata per unit area, the thickness of the palisade and spongy parenchyma, and the amount of intercellular air spaces. Numerous measurements were made of each criteria and standard deviations and standard errors were calculated. All significant results were significant at the five percent level of confidence.

There was a significant difference in the vessel diameter, vessel length, and the thickness of the cork tissue in both the root and the stem from the two different habitats. In both the root and the stem, there was no significant difference in the number of vessels per unit area.

There was very little differentiation in the anatomy of leaves from the two habitats. There was a slight difference in the thickness of the cuticle and a significant difference was found in the amount of intercellular air spaces in the spongy parenchyma.

The roots and stems of plants growing in the mesic habitat had thicker cork tissue, smaller diameter vessels, and slightly longer vessels than the roots and stems from the plants in the shelterbelt. The leaves of the plants from the mesic habitat had thinner cuticle layers and larger intercellular air spaces than those collected in the shelterbelt.

ACKNOWLEDGMENTS

The author wishes to express his gratitude to Dr. G. W. Tomanek for suggesting this problem, for helpful aid and advice, and for reading and criticizing this manuscript. Acknowledgments are also given to Dr. E. P. Martin for helpful criticism in the preperation of this paper and to Mr. Henry McFarland for his valuable assistance in the photography.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

Figure Page

INTRODUCTION

Within the last decade, much work has been done through the cooperation of local, state, and national agencies in an effort to solve a major water conservation problem caused by a group of plants known as phreatophytes. Phreatophytes are plants which grow in areas where the water table is relatively high, usually less than ten feet below the soil surface (Fletcher and Elmendorf 1955). The roots of these plants extend to the water or to the capillary fringe just above the water table. Because underground water is a controlling factor in the distribution of these plants, they are usually found growing along irrigation canals, streams or reservoirs (Marks 1950).

Salt cedar (Tamarix pentandra Pall.) appears to be one of the major phreatophytes. This member of the Tamaricaceae family is a native of the Mediterranean region and has been used extensively in this country as an ornamental shrub (Little 1953, Wilson 1944). These plants are often used as shelterbelts and windbreaks at elevations of less than 5,000 feet in all but unusually cold locations (Gill 1949). Since the introduction of this phreatophyte into the southwestern part of the United States, it has become naturalized and widely distributed and has now become a major part of the water conservation problem. It has been estimated that these plants may waste as much as 20 to 25 million acre feet of water annually (Robinson 1952). As a result of this infestation much work has been done on the ecology and life history of this plant in order to find some possible means of eradication and control (Fort Hays Kansas State College 1956, 1957, 1958).

Salt cedar has the ability to adapt to many different types of habitats. This phreatophyte may be found growing in xeric chalk flats, in heavy clay loam soils, and in mesic sand bars near streams. It was the purpose of this study to determine any differentiation in the internal anatomy of the plant due to a difference in the type of habitat in which it was growing. The writer was primarily interested in the water conduction tissue of the plants, especially in the diameter of the vessel tubes, the length of the vessel tubes, and the number of vessel tubes per unit area.

It has been found that plants of salt cedar growing in a mesic habitat will transpire water at a greater rate than plants growing in a xeric habitat (Fort Hays Kansas State College 1957). The information obtained from this study should be beneficial in determining the ability of the salt cedar to adapt itself to different habitats.

RELATED LITERATURE

Since the importance of salt cedar in relation to water control was recognized a few years ago, various agencies have started research programs in an effort to find a control of this unwanted phreatophyte. Salt cedar appears of little value economically and thus remains a problem requiring control (Gatewood *et al.* 1950).

Little work has been done on the internal anatomy of the salt cedar. Pujiula (1950) observed the anatomy of the leaves (especially their secretory ducts) of a closely related plant, *Schinus nolle*, and the distribution of green tissue in salt cedar leaves. Paroli (1940) worked with the embryological development of the salt cedar. Joshi

and Kajale (1936) described the structure and development of the embryo sac, ovule, and fruit of Tamarix diocia Roxb. Merkel (1957) worked with the root and shoot development of the young seedlings of salt cedar. He found that during the early part of the development of the seedling, the base of the hypocotol enlarged forming a ring-like structure. The cortical tissue of the primary root was quite transparent in contrast to the darker stele.

The external development of the roots of the salt cedar seedlings appeared greatly dependent upon moisture relationships in the soil including the degree of saturation near the surface and the position of the water table. The early development of the shoot was confined mainly to the production of scale-like leaves (Merkel 1957).

METHODS

Two rather distinct habitats were selected to study the difference in the internal anatomy of salt cedar growing under different environmental conditions. One habitat was located approximately one mile east of Schoenchen, Kansas, on the Smoky Hill River. The other habitat was a shelterbelt on the college farm located just west of Hays, Kansas.

The habitat near Schoenchen, Kansas, was a mesic habitat. The salt cedar were growing in sand bars near the water (Fig. 1). In this particular habitat, lack of water was not a controlling factor in the development of the plants.

The plants from the shelterbelt were growing in heavy clay loam soil where water availability may often become a limiting factor (Fig. 2).

Figure 1. General view of salt cedar growing in sand bars near the water. Other vegetation includes willows and cottonwoods.

Figure 2. General view of shelterbelt of salt cedar where water may often become a limiting factor.

The plants from this area had more fully developed root systems and were slightly larger than the plants growing in the sand bars (Merkel and Hopkins 1957).

Samples of the roots, stems, and leaves were taken from each locality. The samples removed were all of the same year's growth to eliminate any growth differences from year to year. The samples were placed in a solution of F. A. A. to fix and kill the tissues. The F. A. A. solution consisted of 40% formaldehyde, 40% acetic acid, and 20% ethyl alcohol. The samples were left in the F. A. A. solution until they were sectioned with a microtome. Cross sections and longitudinal sections of the roots and stems were made on a sliding microtome. These samples were sectioned to a thickness of 15 microns. The samples were stained with safranin and fast green to distinguish the difference in the tissues and were then mounted on slides using piccolyte as a mounting medium.

The leaves were embedded in paraffin and sectioned both longitudinally and radially on a ribboning microtome to a thickness of 15 microns. They were then stained and mounted with the same process used for the roots and the stems.

The four major criteria used to measure the difference in the anatomy of the stems and the roots were the diameter of the vessel tubes, the abundance of the vessel tubes per unit area*, the length of the vessel tubes, and the thickness of the cork tissue. The criteria used to measure the difference in the anatomy of the leaves were the thickness

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* The unit area used was a square superimposed upon an ocular eyepiece. The unit area was not calculated as the writer was interested only in relative abundance.

of the cuticle, the number of stomata per unit area, the thickness of the palisade and spongy parenchyma, and the amount of intercellular air spaces.

The diameter of the vessel tubes, the length of the vessel tubes, and the thickness of the cork tissue in the roots and stems were measured in microns with the aid of an ocular eyepiece which had been calibrated on a stage micrometer. The abundance of vessels per unit area was measured with the aid of a Whipple counting disc. All measurements in the leaves were made with the aid of an ocular eyepiece, with the exception of the number of stomata per unit area, which was measured with a Whipple counting disc.

Numerous measurements were made of each criteria and standard deviations and standard errors were calculated. All significant results were significant at the five per cent level of confidence.

Photomicrographs were taken of the slides which showed the major developmental characteristics.

RESULTS

General Anatomy of the Stem

The internal anatomy of the stem of salt cedar was typical of the stems of most woody angiosperms. The stelar type was an ectophloic siphonostele. The development of the primary xylem was endarch in nature. The vessels of the protoxylem were characterized by annular and helical secondary thickening. The vessels of the metaxylem were characterized by reticulate and pitted types of secondary thickening.

The pith of the salt cedar was fairly large and was composed of thin-walled parenchymatous tissue. The cells were tetrahedral in shape and contained large intercellular air spaces (Fig. 3).

The secondary xylem was composed mainly of vessels and fibers. Other tissue in the secondary xylem consisted of xylem parenchyma and a few small tracheids. Vascular rays which were multisereate extended from the pith to the phloem (Fig. 4). There seemed to be no specific arrangement of the vessel tubes. Some of the vessels were solitary and some of them were united in groups of two or three (Fig. 5).

A cross section of a stem of salt cedar which was three years old revealed a ring-porous type of wood (Fig. 6). Cross sections of a stem of salt cedar which was one year old revealed a diffuse-porous type of wood (Fig. 5). The distribution of vessels in a given species may vary in relation to environmental conditions and is subject to change with the increasing age of a tree (Esau 1953). The ring-porous condition appears to be highly specialized and occurs in comparatively few plants, nearly all being species of the north temperate zones (Gilbert 1940).

The cambium of the salt cedar was complete with no branch gaps or leaf gaps and was composed of fusiform initials and ray initials. The fusiform initials gave rise to all the cells of the secondary xylem and phloem. The ray initials gave rise to the cells in the lateral rays.

The secondary phloem was formed from the fusiform initials of the cambium. The basic components of the secondary phloem were the sieve

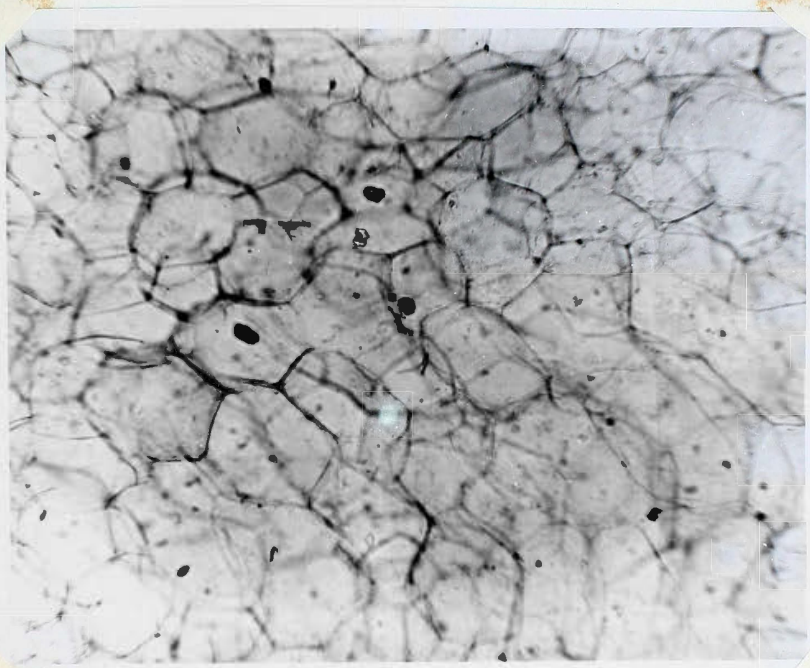

Figure 3. Cross section of pith of young stem of salt cedar showing thin-walled parenchyma cells and large air spaces. (Magnification approximately 100).

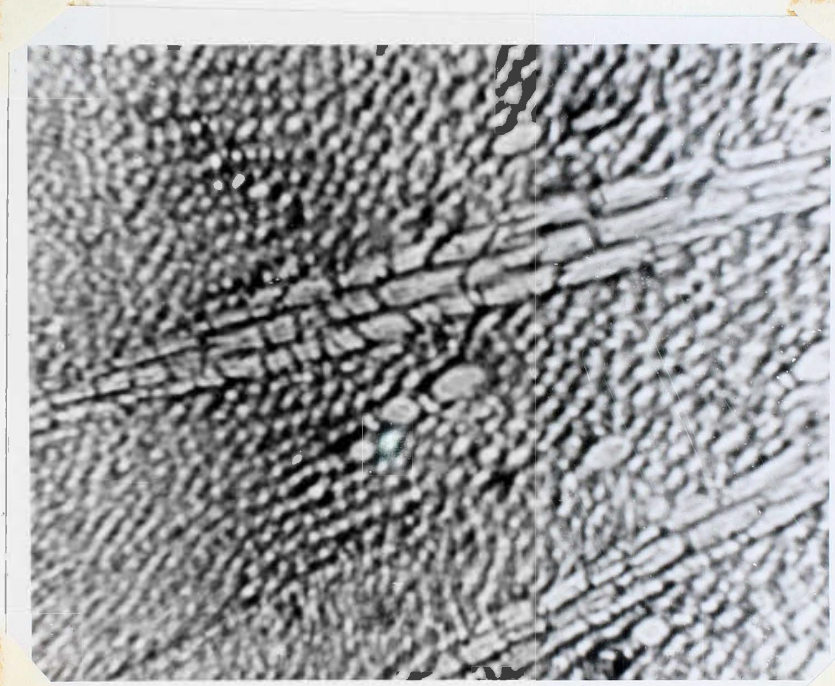

Figure 4. Vascular rays in secondary xylem of young stem. The rays were all multisereate. (Magnification approximately 150).

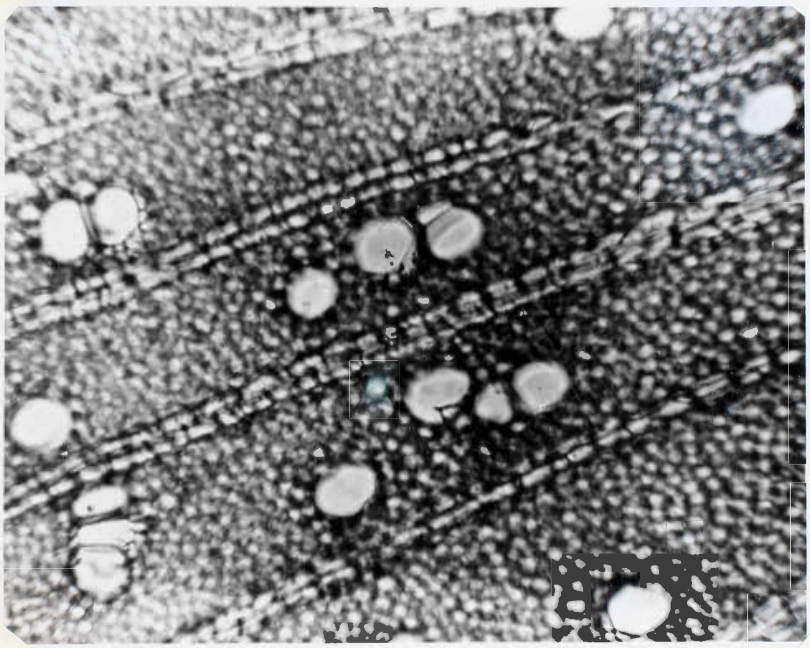

Figure 5. Cross section of young stem showing large vessels between the lateral rays. Some of the vessels were solitary and some were grouped. (Magnification approximately 100).

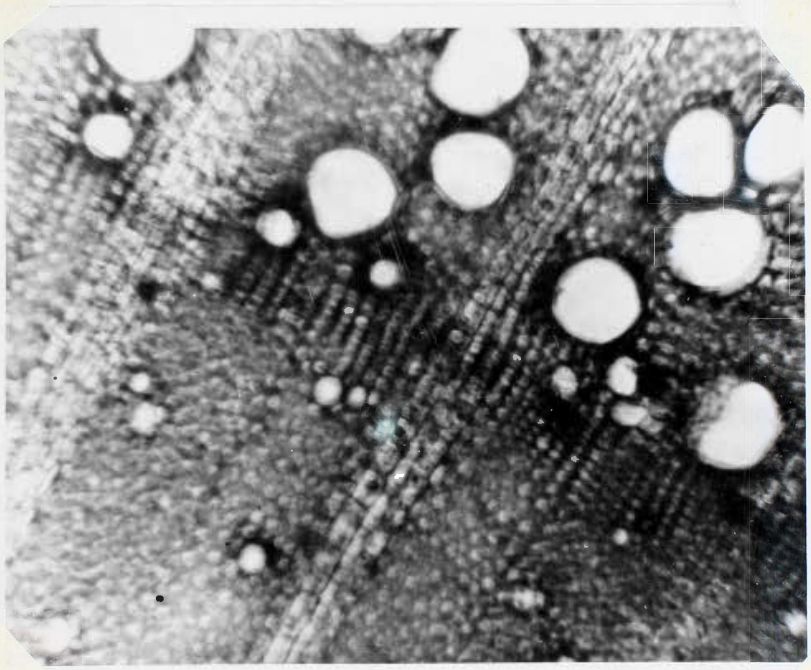

Figure 6. Cross section of three year old stem showing a ring-porous condition. The large vessels are in the spring wood and the small vessels are in the summer wood. Note the annual growth ring. (Magnification approximately 100).

tubes, companion cells, fibers and sclereids. Older secondary phloem was sloughed off with the development of new secondary phloem. The primary phloem was crushed in the younger stems and was crowded into the cortex by the centrifigual action of the cambium (Fig. 7). This primary phloem was sloughed off with the bark in the older stems.

The cortex of the young plant consisted primarily of parenchyma tissue with small strengthening bundles of collenchyma and sclerenchyma fibers. In the older plants this cortex was sloughed off with the bark.

The periderm consisted of three distinct regions. They were the phellem, the phellogen and the phelloderm (Fig. 8). The phellogen is the meristematic tissue (often referred to as the cork cambium) which produces the phellem to the outside and the phelloderm to the inside. The phellem (or cork tissue) was highly suberized and ranged from five to seven layers in thickness.

Differences due to Habitat

The water available to the plant seemed to have a controlling effect upon the thickness of the cork tissue. Care was taken to select samples of the same age to eliminate any possibility of variations due to a difference in the yearly growth. The samples obtained were one year old. The cork tissue from the plants growing in the mesic habitat was between 10 and 15 microns thicker than the same tissue from a plant growing in the shelterbelt (Table I). There seemed to be no difference in the quantity of suberization of the cork cells. The cells of the cork tissue seemed to be slightly larger in the stems from the mesic

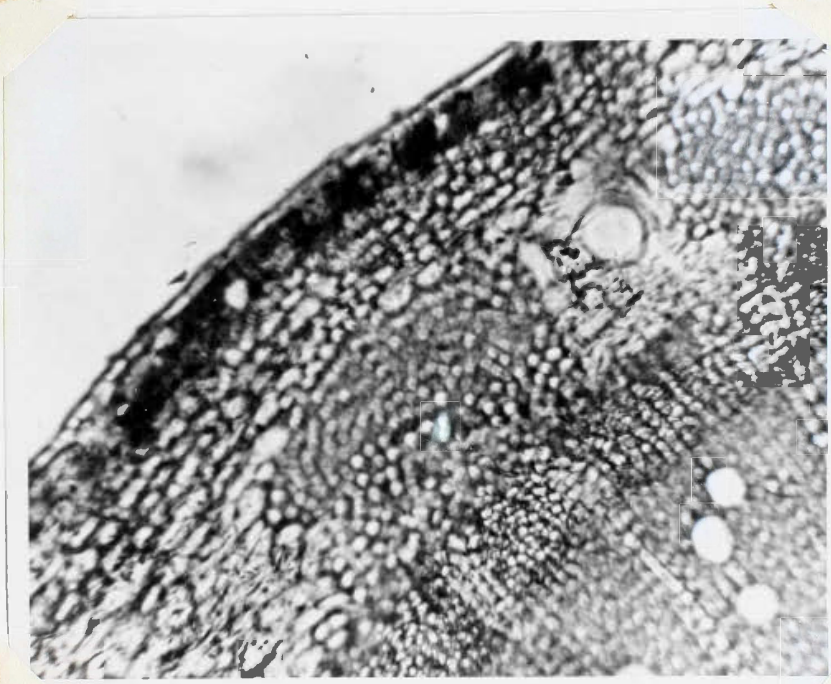

Figure 7. Cross section of young stem of salt cedar showing the crushed primary phloem crowded into the cortex. (Magnification approximately 100).

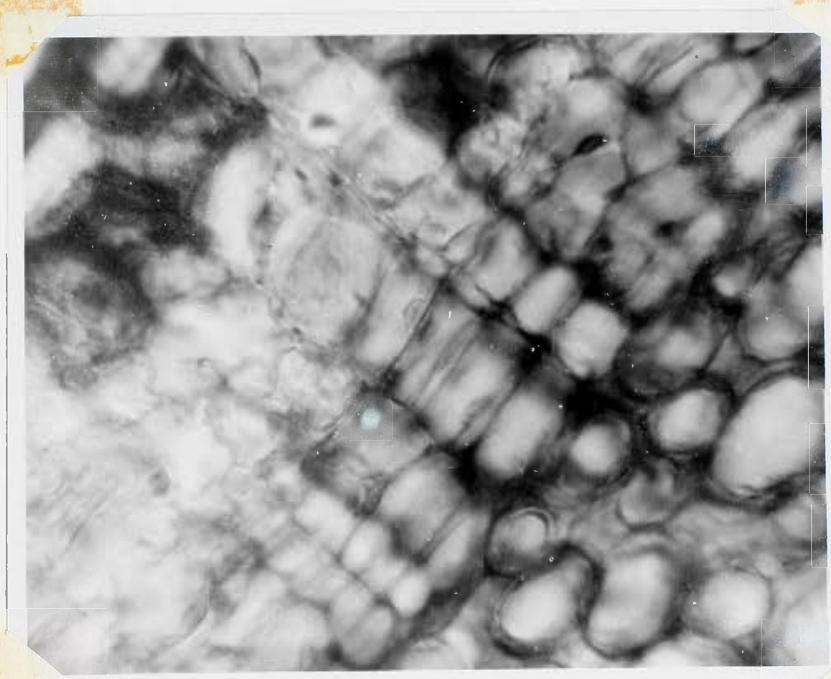

Figure 8. Cross section of young stem showing the cork cambium. The three dark layers of elongated cells are the periderm. Highly suberized cells to the top are cork cells and the lower cells are the cortex. (Magnification approximately 430).

Table I. Differences in internal anatomy of stem from shelterbelt and from sandbar. All measurements are expressed as microns with the exception of number of vessels per unit area. Confidence limits are at the five per cent level of confidence.

CRITERIA	SHELTERBELT	SANDBAR
	Mean	Mean
vessel diameter	61.56 ± 5.34	49.00 ± 2.04
vessel length	95.41 ± 3.98	104.37 ± 5.62
vessels per unit area	3.78 ± 0.42	3.18 ± 0.38
thickness of cork	61.88 ± 3.88	75.89 ± 3.54

habitat where the water was more available. The range in thickness of the cork tissue was nearly the same in both localities. Of all measurements taken, the thinnest cork tissue in the shelterbelt was 49 microns and the thinnest in the mesic habitat was 59.5 microns. The thickest cork tissue from the shelterbelt was 87.5 microns and the thickest in the mesic habitat was 105 microns. The mean thickness of the cork tissue at the five per cent level of confidence was 61.88 ± 3.88 microns in the shelterbelt and 75.89 ± 3.54 microns in the mesic habitat (Table I). The smaller size of the cork tissue of the plants growing in the drier habitat can be explained by the adaptation of plants to their water supply. A decrease in the water available to the plant affects the cell metabolism and results in modifying the form and size of the various tissues (Weaver and Clements 1938). The faster metabolic rate of the cells of the plants growing in the mesic habitat probably caused the cells to be slightly larger.

The greatest variance encountered in the study of the stems was the diameter and length of the vessel tubes. The diameter of the vessels in the shelterbelt ranged from 42 to 87.5 microns while the diameter of the vessels of the plants growing near the water ranged from 38 to 70 microns. Contrary to preconceived ideas of the author, the vessels of the plants in the water habitat were significantly smaller than those of the plants growing in the shelterbelt (Table I). The mean diameter of the vessel tubes of the plants in the mesic habitat was 49.00 ± 2.04 microns while the mean diameter of the vessels in the shelterbelt was 61.56 ± 5.34 microns (Table I).

Although the vessel tubes of the plants growing in the shelterbelt were larger in diameter, they were not as long as the vessels growing in the mesic habitat (Table I). The length of the vessels ranged from 87.5 to 140 microns in the mesic habitat and from 73.5 to 126 microns in the stems from the shelterbelt. The mean length of the vessel tubes in the shelterbelt was 95.41 ± 3.98 microns while the mean length of the vessel tubes in the mesic habitat was 104.37 ± 5.62 microns (Table I).

Even though the vessels in the stem of the plants from the shelterbelt were slightly larger in diameter, there was no significant difference in the abundance of the vessels per unit area between the two habitats (Table I). The mean number of vessel tubes per unit area was 3.78 ± 0.42 in the shelterbelt and 3.18 ± 0.38 in the mesic habitat (Table I). The plants of the same size had approximately the same number of vessel tubes.

Of the many factors which could cause the difference in the diameter and length of the vessel tubes, one was probably the metabolic activity of the xylem parenchyma and the fibers which surrounded the xylem vessels. During the early stages of the development of the vessels, the metabolic activity of the cells surrounding them would have been greater in an area where the water was more available. This could conceivably have caused an enlargement of the parenchyma cells and caused a retarding effect upon the centrifigual development of the vessels. In an area where the water availability may become critical, the metabolic rate of the cells may be lessened. Therefore, the parenchyma cells would not have as much of a retarding effect and the

vessels would be more conducive to centrifigual growth, causing a larger diameter vessel where the water was more critical. The retarding effect of the xylem parenchyma would cause the vessels to grow in a longitudinal direction and become slightly more elongated.

General Anatomy of Root

The internal anatomy of the root differed from that of the stem in the absence of internal pith. The xylem formed a solid central strand and was surrounded by phloem. This simple and most primitive type of stele is known as a protostele. The lignification of the primary xylem began at the periphery of the root and proceeded toward the axis in a centripetal direction (Fig. 9). This condition is known as exarch. The exarch type of lignification of the primary xylem and the protostelic type of stele are considered to be low on the evolutionary scale of development and are typical of roots of plants (Haupt 1953). The greater uniformity of the underground habitat, as contrasted with the aerial habitat, caused the root to retain some of the primitive structural features which eventually disappeared in the stem (Esau 1953).

The secondary thickening of the protoxylem and the metaxylem was the same in the root as in the stem. The protoxylem was characterized by annular and helical thickening and the metaxylem had reticulate and pitted types of secondary thickening.

The central part of the young root was occupied by the vascular cylinder composed of the vascular system and the associated parenchyma. The vascular system was compactly arranged and was not interrupted by

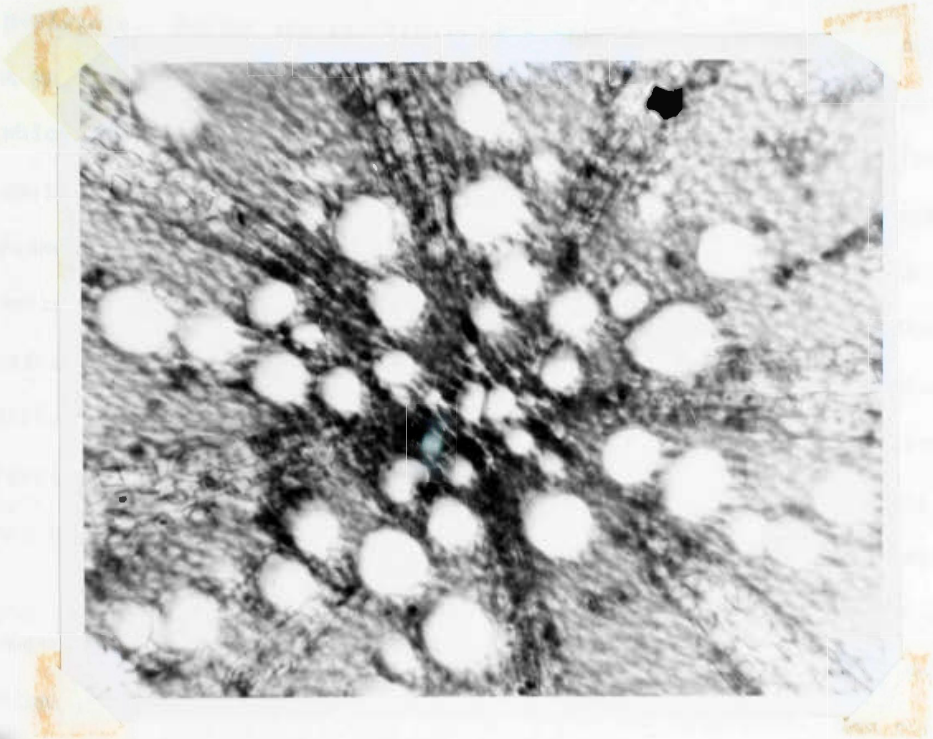

Figure 9. Cross section of young root showing the exarch protostele. (Magnification approximately 100).

gaps. The vascular body was surrounded by a distinct uniserate tissue zone known as the pericycle, which was in turn surrounded by the endodermis. The pericycle of the young roots consisted of thin-walled parenchyma. Secondary roots arise in this meristematic tissue zone (Fig. 10). Merkel (1957) found that in young seedlings of salt cedar secondary root development began during the third week after germination. Each secondary root was first evident as a slight enlargement in the pericycle. During the initiation of a secondary root in an angiosperm, a group of pericycle cells undergo periclinal and anticlinal divisions which eventually result in the formation of a protrusion, the lateral root primordium (Esau 1953). By continued growth, the lateral root primordium gradually penetrated the cortex. Before the primordium emerged on the surface of the parent root, the apical meristem, the primary tissue regions of the young root axis, and the rootcap became differentiated (Fig. 11). The cortical layer was later forced outward forming an obvious swelling at the side of the root. This swelling enlarged and finally ruptured as the secondary root continued growth.

The majority of the internal tissue of the root of salt cedar was composed of secondary xylem. The principal components of the secondary xylem were vessels, xylem parenchyma, fibers and tracheids. The roots possessed a higher porportion of parenchyma cells than the stems and these cells contained a greater accumulation of starch grains. Like the stems, the older roots revealed a ring-porous type of wood. The vessels of the roots were very similar to those of the stem.

The rays of the roots were also multisereate and seemed to contain more stored starch and other food materials than the rays of the stem.

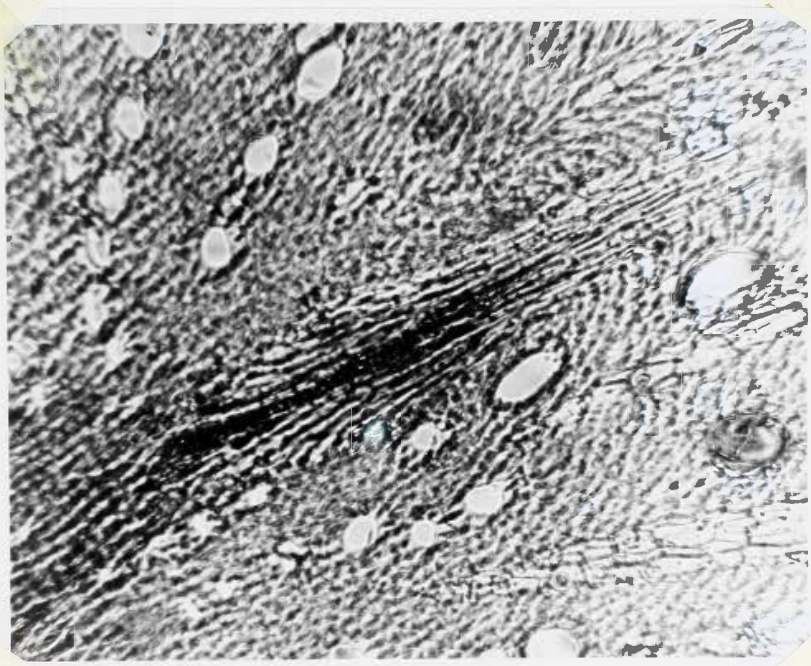

Figure 10. Cross section of root showing a branch root which had originated in the pericycle. The pericycle has since moved toward the periphery of the plant because of the action of the cambium. (Magnification approximately 100).

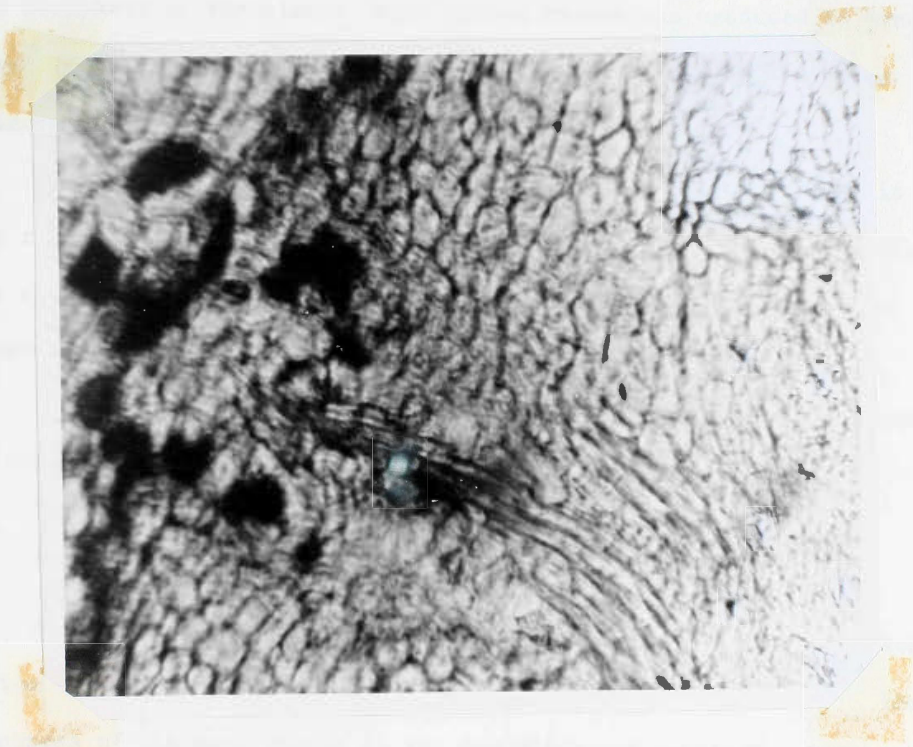

Figure 11. Cross section of young root showing rootcap of the secondary root moving through the cortex. Dark areas are crushed cortical cells. (Magnification approximately 100).

The vascular cambium appeared first on the inner edge of the primary phloem. With the development of the secondary xylem and secondary phloem, the cambium was forced outwards and soon became concentric with the primary xylem. With the development of new secondary xylem by the fusiform initials of the cambium, the primary xylem was completely embedded. The fusiform initials of the cambium produced secondary phloem toward the periphery of the plant. This phloem tissue was produced in annual layers and parts of it were sloughed off with the bark in the older plants (Fig. 12). The primary phloem was crushed and sloughed off.

The cortical layer of the root appeared outside the endodermis and was composed mostly of parenchyma cells which had large intercellular air spaces (Fig. 13). Starch was stored in these parenchyma cells. Small amounts of sclerenchyma fibers were present.

The cork tissue of the roots seemed more suberized and was slightly thicker than the cork tissue of the stems (compare Figs. 7 and 13).

Differences due to Habitat

Samples of the roots used to measure the difference in the internal anatomy were one year old. There was a significant difference in the thickness of the cork tissue in the two different habitats. The cork tissue from the plants growing in the mesic habitat (river sandbar) was approximately 15 microns thicker than the plants growing in the shelterbelt (Table II). There seemed to be no difference in the quantity or quality of suberization of the cork cells from the habitats. As was the case with the stems, the cork cells from the mesic habitat were slightly larger than those from the shelterbelt. This enlargement was

Figure 12. Cross section of root showing layers of phloem tissue. Dark line through the center is the vascular cambium. (Magnification approximately 100).

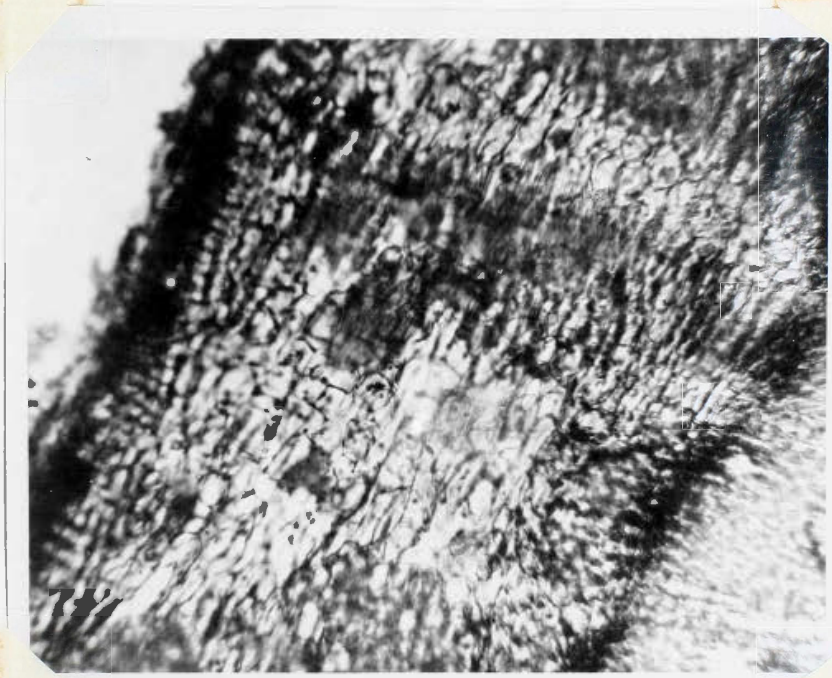

Figure 13. Outer area of root showing cortex and intercellular air spaces. Note the thick cork layer. (Magnification approximately 100).

Table II. Differences in internal anatomy of root from shelterbelt and from sandbar. All measurements are expressed as microns with the exception of number of vessels per unit area. Confidence limits are at the five per cent level of confidence.

CRITERIA	SHELTERBELT	SANDBAR
	Mean	Mean
vessel diameter	96.11±5.76	41.50±3.54
vessel length	148.94±2.56	159.76±2.94
vessels per unit area	2.20±0.36	2.10±0.24
thickness of cork	130.41±4.44	149.10±4.72

probably caused by the increased metabolic rate of the cells in the mesic habitat. The range in thickness of the cork tissue was slightly greater in the mesic habitat than it was in the shelterbelt. Of all the measurements the thinnest cork tissue was 108 microns in the shelterbelt and 120 microns in the mesic habitat. The mean thickness of the cork tissue in the mesic habitat and the shelterbelt was 149.10±4.72 and 130.41±4.44 microns, respectively (Table II). In both the roots and the stems, an increased water supply was conducive to thicker layers of cork tissue.

The greatest difference encountered in this study was in the vessel diameters of the roots. The diameter of the vessels in the roots from the shelterbelt was more than twice as large as in those from the mesic habitat (Table II). The diameters of the vessels in the shelterbelt ranged from 66 to 133 microns. The diameters of the vessels in the mesic habitat ranged from 24 to 77 microns. The mean diameter of the vessels in the shelterbelt was 96.11±5.76 microns and 41.50±3.54 microns in the vessels of the mesic habitat (Table II).

The vessels of the roots followed the same general pattern as those of the stems in relation to length and diameters. The vessels of the roots were significantly longer in the mesic habitat than in the shelterbelt (Table II). They ranged in length from 120 to 171 microns in the shelterbelt and from 135 to 183 microns in the mesic habitat. The mean length of the vessel tubes in the shelterbelt was 148.94±2.56 microns and 159.76±2.94 microns in the mesic habitat (Table II).

The roots growing in the two different habitats had approximately the same number of vessels, even though the vessels from the shelterbelt

were more than twice as large as those from the mesic habitat. There was no significant difference in the number of vessels per unit area in the two different habitats (Table II). The mean number of vessel tubes per unit area was 2.10±0.24 in the mesic habitat and 2.20±0.36 in the shelterbelt. There was a significant difference in the number of vessel tubes per unit area between the roots and the stems in each of the two different habitats (Table I).

A plentiful water supply and a coarsely textured soil seemed to be conducive to small vessels, whereas a heavy soil and a low water supply favored the development of large vessels. The low water content in the shelterbelt would reduce the metabolic activity of the parenchyma cells surrounding the vessels and would be favorable for the centrifigual development of the vessels. Also, the heavy soil would exert a greater pressure on the thin-walled parenchyma cells than on the thick-walled vessels and they would not be as likely to expand as the vessels. The reverse condition would be true of the vessels growing in the mesic habitat. The high water availability would increase the metabolic rate of the parenchyma surrounding the vessels and would be conducive to the enlargement of the parenchyma cells. This caused a retarding effect upon the centrifigual development of the vessels. In like manner, the coarser soil would be more favorable for the development of the thin-walled parenchyma. Although no measurements were made of the parenchyma cells, general observations made showed them to be larger in the mesic habitat.

General Anatomy of the Leaf

The leaf of the salt cedar differed from that of most other woody angiosperms in that it was scale-like. Numerous small scale-like leaves appeared on each branch and were supplemented by minute scale-like bracts. The leaves, like the leaves of most other plants, contained no secondary tissue, no periderm, and no storage tissue. The leaf is considered to be a food producing tissue and not a storage organ. In most angiosperms the main part of the photosynthetic tissue is typically expanded to a flattened structure. However, the salt cedar displayed a leaf which was nearly round in shape. There was a slight differentiation between the adaxial and the abaxial side of the leaf. On the adaxial side, where the light was more intense, the palisade parenchyma cells were slightly larger. New leaves developed by lateral meristems which appeared in the axis of the scale-like leaves (Fig. 14). The older leaf continued growth by the activity of the apical meristem.

The epidermis was one cell layer thick and devoid of chlorophyll. This layer of cells completely surrounded the leaf. There was no evident differentiation in the thin-walled parenchyma cells of the epidermis, all of them being approximately the same size. The only other type of cells in the epidermis was the guard cells which surrounded the stomata. These guard cells contained a few chloroplasts. The close fitting parenchyma cells of the epidermis contained a thick layer of cuticle. Not only was the cuticle on the surface of the epidermis, but it also impregnated the cell walls (Fig. 15). Hydathodes were present in the epidermis at the apical end of the leaf. These

Figure 14. Longitudinal section of leaf showing the development of a new leaf by a lateral meristem in the axil of a scale-like leaf. (Magnification approximately 100).

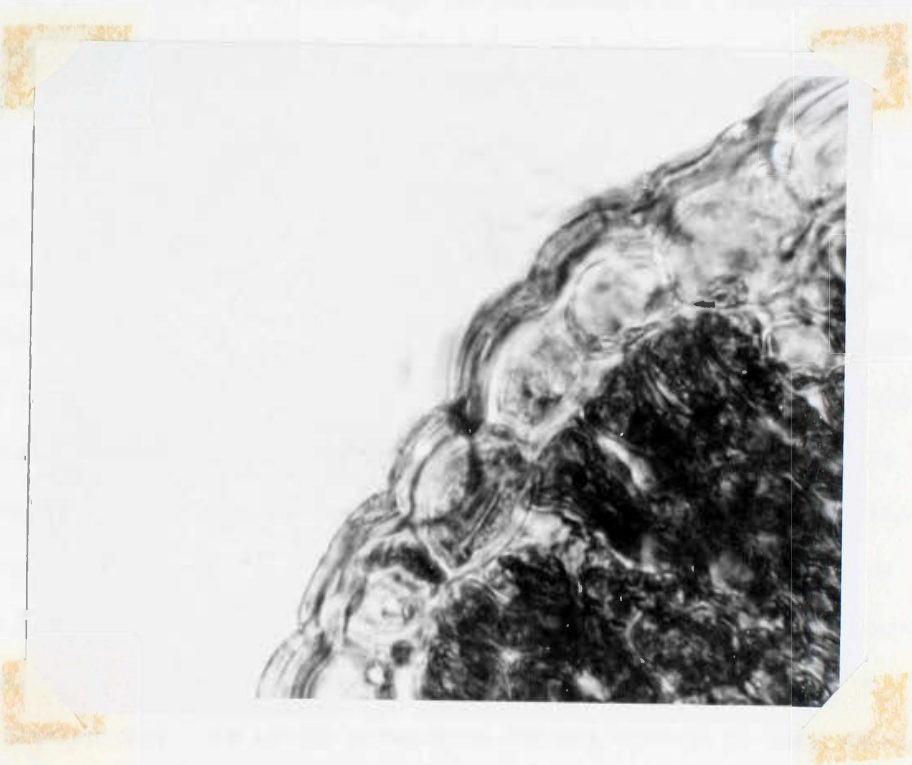

Figure 15. Cross section of leaf showing the epidermis impregnated with cuticle. Note the stomata present near the third cell from the bottom. (Magnification approximately 430).

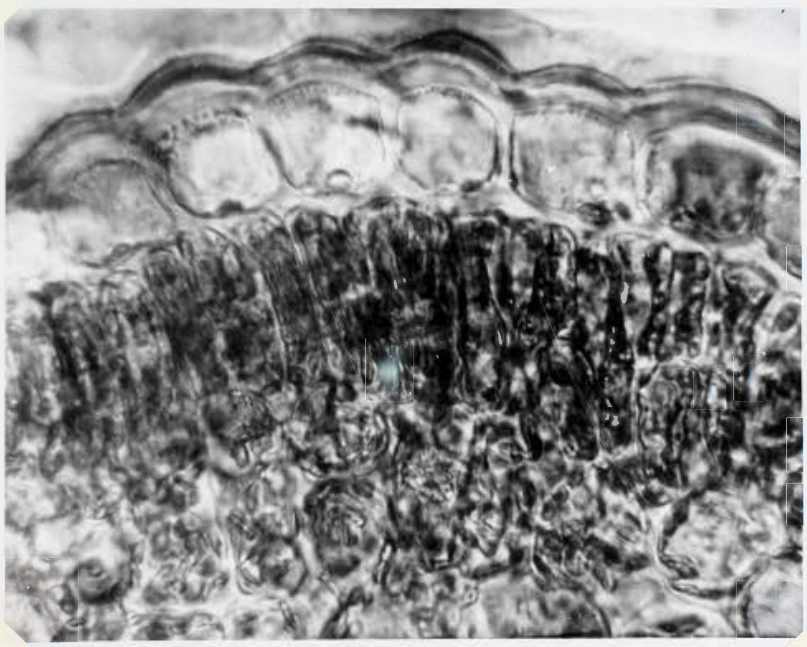

Figure 16. Cross section of leaf showing the elongate-prismatic cells of the palisade parenchyma. (Magnification approximately 430).

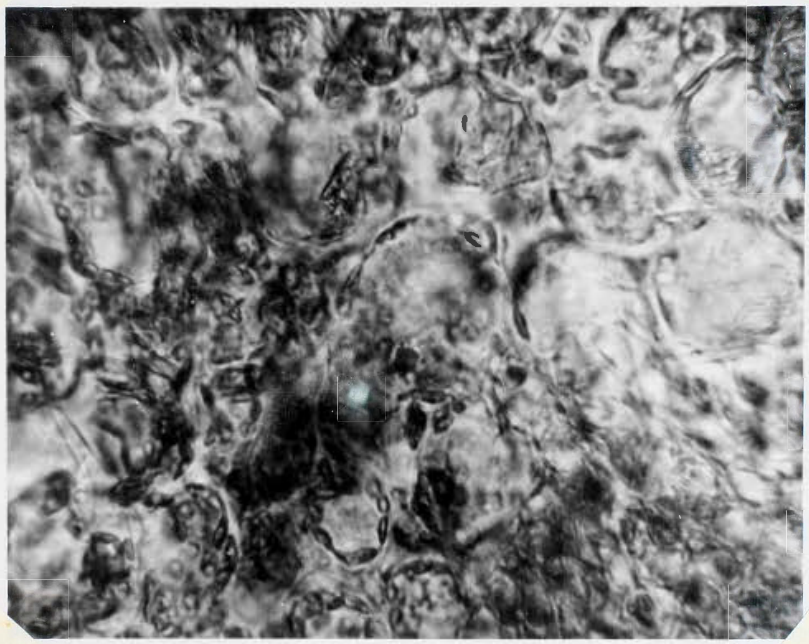

Figure 17. Cross section of leaf showing the spongy parenchyma. Note the large intercellular air spaces and the chloroplasts lining the cell walls. (Magnification approximately 430).

surrounding the leaves affected the thickness of the cuticle of the leaf by the slower oxidation rate. The higher humidity slows down the oxidation rate of the fatty acids and therefore retards the development of the cuticle (Weaver and Clements 1938). It was possible that the relative humidity was higher in the habitat near the water.

There was no significant difference in the thickness of the mesophyll (the palisade and spongy parenchyma) from the two habitats. In both habitats the thickness of the mesophyll was near 150 microns (Table III). There was a large variance in the thickness of the mesophyll within the individual specimens. Where the light was more favorable, the mesophyll was the thickest due to an increase in the palisade parenchyma. The mesophyll ranged from 123 to 226 microns in thickness. The mean thickness of the mesophyll in the shelterbelt was 144.78 ± 5.62 microns and 156.39 ± 6.93 microns in the mesic habitat (Table III). The thickness of the mesophyll of the leaf seemed to be governed more by the available light than by available water.

Measurements of intercellular air spaces in the mesophyll were made only in the spongy parenchyma as the palisade parenchyma was fairly compact. Significant differences were found in the intercellular air spaces of the spongy parenchyma (Table III). Plants from the mesic habitat had larger intercellular air spaces than those from the shelterbelt. Measurements were estimated as to average distance between the cells, as the cells were very irregular. The mean distance between the cells of the spongy parenchyma in the mesic habitat was 21.34 ± 2.01 microns and 17.46 ± 1.72 microns in the shelterbelt (Table III).

Although no measurements were made of the size of the cells of the spongy parenchyma, observations indicated that they were approximately the same size in both habitats.

The number of stomata per unit area was measured in both the cross sections and the longitudinal sections of the leaves. As many as ten stomata were counted in a cross section of a scale-like leaf. Approximately every fifth cell of the epidermis in the cross sections was interrupted by a stomata. No significant difference was recorded in the number of stomata per unit area in the two different habitats. The mean number of stomata per unit area was 2.31 ± 0.25 in the shelterbelt and 2.50 ± 0.36 in the mesic habitat (Table III).

SUMMARY AND CONCLUSIONS

Salt cedar is a phreatophyte which has created a major water conservation problem in the southwestern part of the United States. This plant has the ability to adapt to many different types of habitats. It may be found growing in xeric chalk flats, in heavy clay loam soils, and in mesic sandbars near streams.

Samples of the roots, stems, and leaves of salt cedar were collected from two distinct habitats and were placed in F. A. A. solution to fix and kill the tissues. The samples were then sectioned, stained, and mounted on slides. The diameter of the vessel tubes, the length of the vessel tubes, the number of vessel tubes per unit area, and the thickness of the cork tissue were the criteria used to measure the difference in the roots and stems between the two habitats. Criteria used to

measure the difference in the anatomy of the leaves were the thickness of the cuticle, the number of stomata per unit area, the thickness of the palisade and spongy parenchyma, and the amount of intercellular air space.

The plants growing in the shelterbelt had stem vessels which were significantly larger in diameter than the stem vessels in the sandbar. However, the vessels of the stem were longer in the mesic habitat than in the shelterbelt. There was no significant difference in the number of vessels per unit area. The cork tissue from the plants growing in the shelterbelt was significantly thinner than the cork tissue of the plants growing in the sandbar.

The internal anatomy of the root was quite similar to that of the stem in relation to the criteria measured. In the shelterbelt the vessels of the root were more than twice as large in diameter as in the mesic habitat. Like the stems, the vessels of the roots from the sandbar were longer. Again there was no significant difference in the number of vessels per unit area. The cork tissue was thicker in the sandbar than it was in the shelterbelt.

Of the three different parts of the plant, the leaf showed the least amount of differentiation due to a difference in the habitat. The internal anatomy of the leaf seemed to be more affected by the available light than by the available water. The cuticle of the leaf was slightly thicker in the shelterbelt than in the sandbar. There was no significant difference in the thickness of the mesophyll. Plants from the mesic habitat had slightly larger intercellular air spaces

than those of the shelterbelt. No significant difference appeared in the number of stomata per unit area.

The major difference in the internal anatomy of the salt cedar in the two different habitats was in the diameter of the vessels. A mesic habitat was conducive to small vessels in both the root and stem while the shelterbelt habitat favored the development of large vessels.

Probably one of the major reasons that the salt cedar transpires a large amount of water is the form and structure of the small scale-like leaves. Nearly half of the leaf was composed of vascular tissue, most of it being xylem elements. The tracheids in the vascular bundles ended freely about one millimeter from the apical end of the leaf. Between the end of the leaf and the vessel tracheids, large amounts of intercellular air spaces were present through which the water could move.

The difference in the transpiration rates of the salt cedar in the two different habitats was probably due to the amount of water available to the plant. The plants growing in the mesic habitat had more water available to be transpired than did those in the shelterbelt.

LITERATURE CITED

Esau, Katherine. 1953. Plant anatomy. John Wiley & Sons, Inc., New York. 735 pp.

Fletcher, Herbert and Harold Elmendorf. 1955. Phreatophytes--a serious problem in the West. U. S. Dept. Agr. Yearbook, p. 423-429.

Fort Hays Kansas State College, Division of Biological Sciences. 1956. Annual report on ecological research of salt cedar and other vegetation primarily at Cedar Bluffs Reservoir, 1956. Unpublished report.

Fort Hays Kansas State College, Division of Biological Sciences. 1957. Annual report on ecological research of salt cedar and other vegetation primarily at Cedar Bluffs Reservoir, 1957. Unpublished report.

Fort Hays Kansas State College, Division of Biological Sciences. 1958. Annual report on ecological research of salt cedar and other vegetation primarily at Cedar Bluffs Reservoir, 1958. Unpublished report.

Gatewood, J. S., T. W. Robinson, B. R. Colby, J. D. Hem, and L. C. Halpenny. 1950. Use of water by bottom-land vegetation in lower Stafford Valley Arizona. Geological Survey Water-Supply Paper 103, 209 pp.

Gilbert, S. G. 1940. Evolutionary significance of ring porosity in woody angiosperms. Bot. Gaz. 102:105-120.

Gill, Lake. 1949. Shade trees for the Rockies. U. S. Dept. Agr. Yearbook, p. 72-76.

Haupt, Arthur. 1953. Plant morphology. McGraw-Hill Book Company, New York. 464 pp.

Joshi, A. C. and L. B. Kajale. 1936. A note on the structure and development of the embryo-sac, ovule, and fruit of Tamarix diocia Roxb. Ann. Bot. 50:422-425.

Little, Elbert. 1953. Check list of the native and naturalized trees of the United States (including Alaska). U. S. Dept. Agr. Handbook No. 41, 412 pp.

Marks, John. 1950. Vegetation and soil relationships in the lower Colorado desert. Ecology 31:176-193.

Merkel, Daniel. 1957. The germination and early development of salt cedar (Tamarix gallica L.). Fort Hays Kansas State College. Unpublished Master thesis.

Merkel, Daniel and Harold Hopkins. 1957. Life history of salt cedar (Tamarix gallica L.). Trans. Kans. Acad. Sci. 60:360-369.

Paroli, Valeria. 1940. Contribute allo studio embriologico delle Tamaricaceae. Ann. Bot. 22:1-18.

Pujiula, J. 1949. Contribucion al conocimiento anatomico-fisiolojico de algunas disposiciones en el reine vegetal. Bul. Inst. Catalana His. Nat. 37:87-97.

Robinson, T. W. 1952. Phreatophytes and their relation to water in Western United States. Trans. Am. Geophysical Union 33:57-61.

Wilson, Richard. 1944. Tree planting and soil erosion control in the southwest. Jour. Forestry 42:668-673.

Weaver, J. E. and F. E. Clements. 1938. Plant ecology, 2nd ed. McGraw-Hill Book Company, New York. 601 pp.